Attrition Loss Analysis for Arsenic Adsorption Media

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Abstract

On January 23, 2006, the United States Environmental Protection Agency (USEPA) maximum contaminant level (MCL) for arsenic in drinking water of 0.010 mg/L takes effect. Many small communities across the nation will struggle to meet this new MCL due to lack of efficient and inexpensive technology. Sandia National Laboratories (SNL) is part of the Arsenic Water Technology Partnership (AWTP), which is researching innovative technologies to reduce arsenic in drinking water, with a specific focus on assisting small and rural communities. The current arsenic-removal technologies being researched involve commercially-available adsorption media with diameters less than 2.00 mm. These media can be pulverized during shipping and use, which produces smaller particles that can clog water treatment systems and require frequent and costly maintenance. In order to minimize this need, an attrition loss analysis was conducted on all media currently being considered by SNL for arsenic removal. The results of this analysis show that many media (Hydroglobe Metsorb) have acceptable attrition losses after shipping. However, the use of some media (Kemiron CFH 24 and ADA Amended Silica) may need to be reconsidered based on high attrition losses.

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Acronyms

AWTP	Arsenic Water Technology Partnership
AwwaRF	American Water Works Association Research Foundation
DOE	Department of Energy
USEPA	United States Environmental Protection Agency
KAFB	Kirtland Air Force Base
MCL	Maximum Contaminant Level
MSDS	Material Safety Data Sheets
NMED	New Mexico Environment Department
SNL/NM	Sandia National Laboratories/New Mexico
WERC	A consortium for environmental education and technology development

1.0 INTRODUCTION

Sandia National Laboratories, New Mexico (SNL/NM) is a government-owned, contractor-operated, multiprogram laboratory overseen by the U.S. Department of Energy (DOE), National Nuclear Security Administration through the Sandia Site Office, Albuquerque, New Mexico. Sandia Corporation, a wholly-owned subsidiary of Lockheed Martin Corporation, operates SNL/NM under Contract DE-AC04-94AL85000.

In January of 2001, the USEPA proposed to lower the standard for arsenic in drinking water from 0.050 mg/L to 0.010 mg/L. This new standard takes effect on January 23, 2006. For small and rural communities in New Mexico with naturally high arsenic concentrations, the costs of implementing treatment technology could be prohibitive. These communities will need significant assistance to achieve compliance with the drinking water standard.

Sandia National Laboratories is providing assistance to these communities as part of the Arsenic Water Technology Partnership, which also includes the American Water Works Association Research Foundation (AwwaRF) and WERC, a consortium for environmental education and technology development. The function of Sandia National Laboratories in this partnership is to conduct field-scale research on commercially-available arsenic removal technologies. This research includes determining the characteristics of each media type.

Sieve analysis was conducted to determine the range of particle sizes of each media and the percentage of media that is crushed during transport. This percentage, also known as attrition loss, represents the amount of material that is damaged during shipping. This material has potential to clog up water treatment systems with fine-grain particles; systems may then require more frequent maintenance, resulting in higher costs for the community. Those media that have less attrition loss are preferable to those with large attrition losses.

2.0 PURPOSE

The particle size analysis was completed to determine the attrition losses of media during shipping and with use in water systems. This analysis is intended to determine the best media to use for individual systems based on the amount of media consumed and the frequency of maintenance on the system. High attrition losses will increase the amount of media needed because more is lost during both system use and maintenance. The frequency of maintenance increases for media with high attrition losses because fine particles create a blockade, which builds up pressure in the system, and are subsequently lost during backwashing. An increase in the frequency of maintenance and the amount of media needed will increase costs for the operation of a community water system.

Media with low attrition losses are preferable because they may require water system owners to purchase less media and may need less maintenance. The purpose of this analysis was to determine the media types with the lowest attrition losses.

3.0 PROCEDURE

Before any analysis began, material safety data sheets (MSDS) for all media were reviewed. The majority of the media used contain iron or titanium oxides with particles smaller than 38 µm. When shaking and disposing of this media, these small particles become airborne and can be inhaled. Therefore, the specific hazards of each media are important to understand and appropriate precautions must be taken.

Media samples were dried in an oven at 105°C overnight (over eight hours) in glass beakers and transferred to airtight Nalgene bottles after drying for storage in the fume hood. Immediately before beginning sieve analysis, approximately 200 grams of media was poured into a glass beaker under the fume hood. The beaker was then placed on a balance located outside the fume hood and minor adjustments were made to obtain 200.00 grams of media.

Nine sieves of sizes ranging from No. 10 (2.00 mm opening) to No. 400 (0.038 mm) were used in this analysis. The empty sieves and the pan were briefly oven-dried before analysis and, once they had sufficiently cooled, individually weighed on a balance and the weight was recorded on a data sheet.

The 200.00 grams of media was then poured into a stack of sieves, which were placed on a sieve shaker within the fume hood. Paper towels were placed around the sieve shaker and wet down with de-ionized water from a squeeze bottle to minimize dust. For each media, sieve analysis was completed using two separate stacks of sieves due to the fact that they would not all fit in the shaker at one time. The first contained sieve numbers 10 (2.00 mm), 18 (1.00 mm), 40 (0.425 mm), 60 (0.250 mm), 80 (0.180 mm), and a pan. The second round of sieves contained numbers 100 (0.150 mm), 200 (0.075 mm), 325 (0.045 mm), 400 (0.038 mm), and the pan. After 15 minutes of shaking with the first stack, media remaining in the pan was transferred to the No. 100 sieve. The pan was placed below the No. 400 sieve and the second stack was shaken also for 15 minutes.

After shaking was completed, the sieves were separated under the hood and transferred individually to the balance to be re-weighed. This weight was recorded on the data sheet. The contents of each sieve were then disposed of into a trash can placed next to the fume hood to contain dust. The bottom of the trash was also lined with damp paper towels and a squeeze bottle of de-ionized water was used to wash down excessive dust on the sides of the trash can. The base of the sieve was brushed with the sieve brush to remove particles stuck within the mesh screen. Sieves were then washed with Alconox soap and a soft sponge and placed in the oven at 105°C to dry completely before re-use.

Calculations for sieve analysis were completed using Excel spreadsheets for each media. Values for Sieve Mass (grams) and Sieve Mass plus Mass of Dry Media (g) were used to calculate the Mass of Media Retained (g) and the Percentages Retained and Passing. The data was then plotted as Particle Diameter vs. Percent Finer, with Particle Diameter on a log scale. From this plot, it was possible to determine the values of D_{10}, D_{30}, and D_{60}, or the diameters corresponding to 10, 30, and 60 percent finer, respectively. Using these values, the Coefficient of Uniformity (C_u) and the Coefficient of Curvature (C_c) were calculated using on these formulas:

$$C_u = \frac{D_{60}}{D_{10}} \qquad C_c = \frac{D_{30}^2}{D_{10}D_{60}}$$

4.0 RESULTS

The attrition loss analysis provided percentages that can be used to make decisions on the most appropriate sorption media to use for pilot projects and long-term community use.

Based on the data from analysis on each media, the percentage of media smaller than the vendor declared range of particle sizes was calculated. This resulting percentage is the attrition loss, and percentages ranged from 0.8 to 32.3 percent (Table 4-1).

Table 4-1. Percent attrition for each media type.

Media	Media Size (Vendor declared)	Percent Attrition*
Hydroglobe Metsorb	16 x 60	0.8
Purolite ArsenXnp	16 x 50	0.8
Kemiron CFH 10	18 x 35	3.1
EaglePicher NXT-2	32 x 200	5.3
ResinTech ASM 10 HP	20 x 40	9.3
Kemiron CFH 12	10 x 18	9.7
Eaglehard ARM200	12 x 40	11.4
Adedge AD33	10 x 35	13.0
DOW Adsorbsia	10 x 60	16.3
Kemiron CFH 24	5 x 10	29.8
ADA Amended Silica	10 x 40	32.2
MEI Isolux	< 400	Inconclusive
Virotec Bauxsol	< 35	Inconclusive

* Calculated based on the percentage of media sample smaller than the smallest sieve size declared by the vendor.

NB: The media stack used did not always correspond exactly with each vendor's declared media sizes. Sieve sizes used in calculations are stated in Table 2.

Percentages of larger and smaller media were also calculated based on the range of media size declared by the media vendor (Table 4-2). The percentage of media larger than the size declared by the vendor indicates that some inconsistencies occur during manufacturing. The percentage of media smaller than the size declared by the vendor represents the amount that is destroyed during shipping. A high percent of media smaller than the vendor-declared range (i.e. high attrition losses) also indicates that the media may be easy to destroy during use in a water system.

Table 4-2. Distribution of particle size percentages for each media type.

Media	Media Size (Vendor declared)	Percent Larger*	Percent in Range†	Percent Smaller‡	Percent Error
Kemiron CFH 10	18 x 35	**0** (>18)	**97.155** (18 x 40)	**3.13** (<40)	0.28
Hydroglobe Metsorb	16 x 60	**3.56** (>18 mesh)	**95.96** (18x60 mesh)	**0.845** (<60 mesh)	0.37
Virotec Bauxsol	< 35	**6.876** (>18)	**93.354** (<18)	--	0.19
ResinTech ASM 10 HP	20 x 40	**0.005** (>18)	**90.88** (18x40)	**9.27** (<40)	0.16
Kemiron CFH 12	10 x 18	**0.200** (>10)	**90.23** (10x18)	**9.7** (<18)	0.12
MEI Isolux	< 400	**8.98** (>400)	**90.105** (<400)	--	1.25
Eaglehard ARM200	12 x 40	**0.01** (>10)	**89.109** (10x40)	**11.376** (<40)	0.5
Adedge AD33	10 x 35	**0.015** (>10)	**87.056** (10x40)	**13.024** (<40)	0.09
Purolite ArsenXnp	16 x 50	**12.455** (>18)	**86.485** (18x60)	**0.825** (<60)	0.23
DOW Adsorbsia	10 x 60	**0.025** (>10)	**84.186** (10x60)	**16.279** (<60)	0.49
EaglePicher NXT-2	32 x 200	**10.496** (>18)	**83.944** (18x200)	**5.315** (<200)	0.25
Kemiron CFH 24	5 x 10	--	**70.419** (>10)	**29.791** (<10)	0.04
ADA Amended Silica	10 x 40	**0.005** (>10)	**68.12** (10x40)	**32.195** (<40)	0.32

*Calculated based on the percentage of media sample larger than the largest sieve size declared by the vendor.

†Calculated based on the percentage of media sample smaller than the smallest sieve size declared by the vendor.

‡ Calculated based on beginning and ending media sample mass used in sieve analysis.

The vast majority of the media falls within the ranges declared by the vendors. Some error results from the use of a No. 40 sieve instead of a No. 35 or No. 32 sieve (0.425 mm instead of 0.500-0.600 mm), which is the size specified by some of the vendors (Adedge AD33, Virotec Bauxsol, and EaglePicher NXT-2).

4.1 Uniformity Coefficient

The uniformity coefficient is the ratio, by weight, of the grain size that is 60 percent finer to the grain size that is 10 percent finer on the grain size distribution curve. This coefficient is an indication of how well sorted the media is. Well sorted material has greater uniformity.

A low uniformity coefficient means that particles are very similar in size and that media generally requires less backwashing. A low uniformity coefficient is also desirable because fine-grained particles will be less likely to clog up the system and allow pressure build-up. High uniformity coefficient means that there is a wide range of particle sizes. For the attrition loss analysis, the uniformity should have a good spread between the sizes declared by the vendor.

Uniformity coefficients for each media were calculated and are shown in Table 4-3.

4.2 Attrition Losses for Each Media

Attrition losses for all sorption media types analyzed range from 0.8 percent to 32.2 percent, with two media types having inconclusive results due to exceptionally small particle size. Media with lower attrition losses are preferable for use; however, this analysis cannot accurately predict the attrition of media being used in a water system. The addition of water, pressure, and backwashing may increase attrition losses.

A summary of attrition losses and other relevant media characteristics are shown in Table 4-3.

Table 4-3. Summary of relevant media characteristics.

Media	Media Size (Vendor declared)	Percent Attrition	Cu	Cc
Purolite ArsenXnp	16 x 50	0.8	1.64	0.91
Hydroglobe Metsorb	16 x 60	0.8	1.97	0.87
Kemiron CFH 10	18 x 35	3.1	1.57	0.93
EaglePicher NXT-2	32 x 200	5.3	4.11	0.87
ResinTech ASM 10 HP	20 x 40	9.3	1.55	0.94
Kemiron CFH 12	10 x 18	9.7	1.70	0.99
Eaglehard ARM200	12 x 40	11.4	1.88	0.91
Adedge AD33	10 x 35	13.0	2.44	0.88
DOW Adsorbsia	10 x 60	16.3	1.91	0.89
Kemiron CFH 24	5 x 10	29.8	1.43	1.43
ADA Amended Silica	10 x 40	32.2	2.00	0.93
Virotec Bauxsol	< 35	Inconclusive	4.78	0.75
MEI Isolux	<400	Inconclusive	--	--

5.0 CONCLUSION

The attrition loss analysis provided valuable information on the different commercially-available media for arsenic removal. High attrition losses indicate that media may be less effective and more expensive, due to increases in the frequency of maintenance and purchase of additional media. The results of this analysis show that many media (Hydroglobe Metsorb) have acceptable attrition losses after shipping. However, the use of some media (Kemiron CFH 24 and ADA Amended Silica) may need to be reconsidered based on high attrition losses.

When determining which is the best media based on attrition loss, it is also important to consider the coefficient of uniformity, which indicates the range of particle sizes.

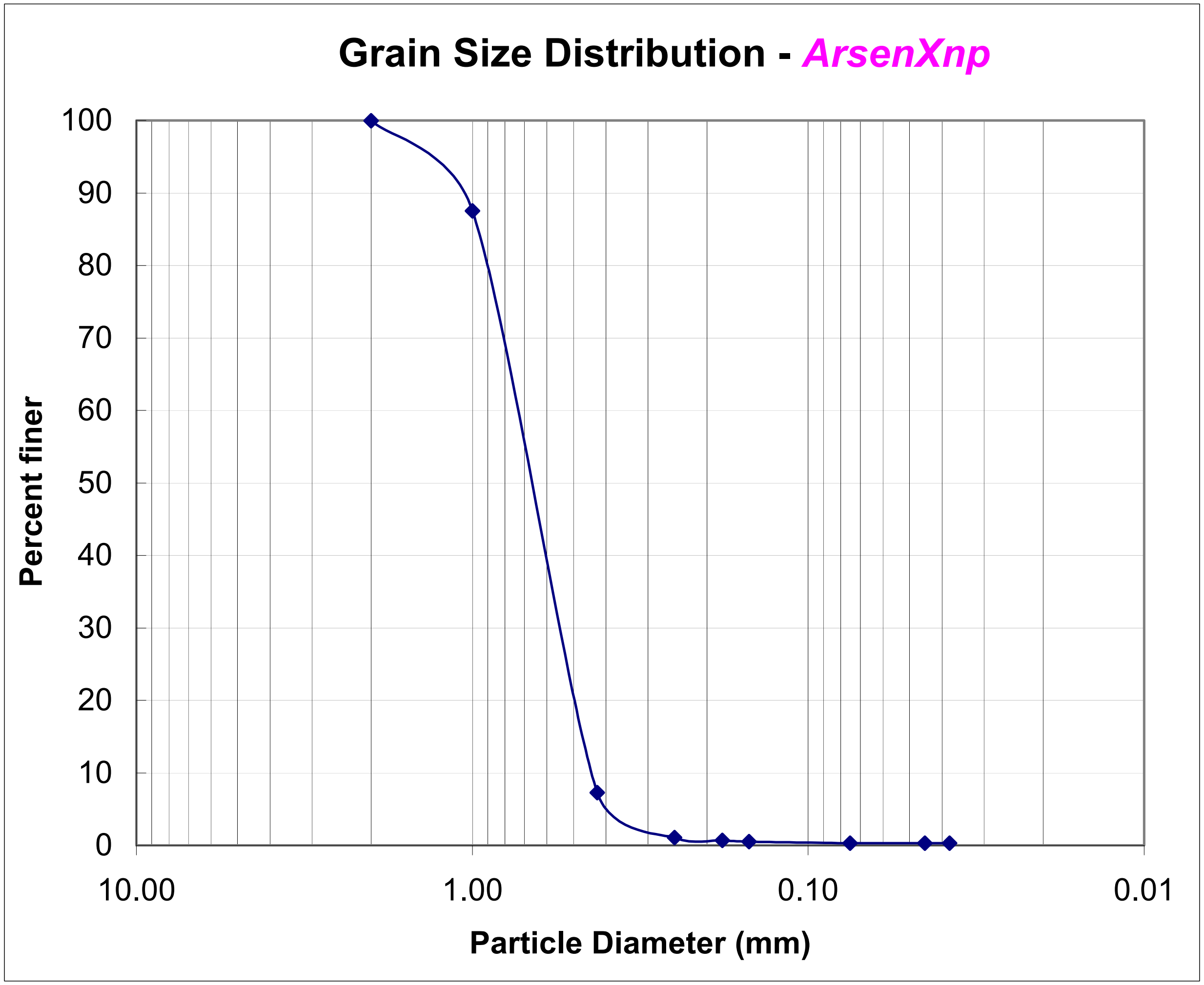
6.0 REFERENCES

1. 40 CFR 141.61, 2002, Title 40, "Protection of Environment," Subchapter D, "Water Programs," Part 141, "National Primary Drinking Water Regulations," Section .61, "Maximum Contaminant Levels for Organic Contaminants," *Code of Federal Regulations*, Office of the Federal Register.

2. Bowles, J. E. (1992). Engineering Properties of Soils and their Measurement. New York, McGraw Hill, Inc., pp. 43-55.

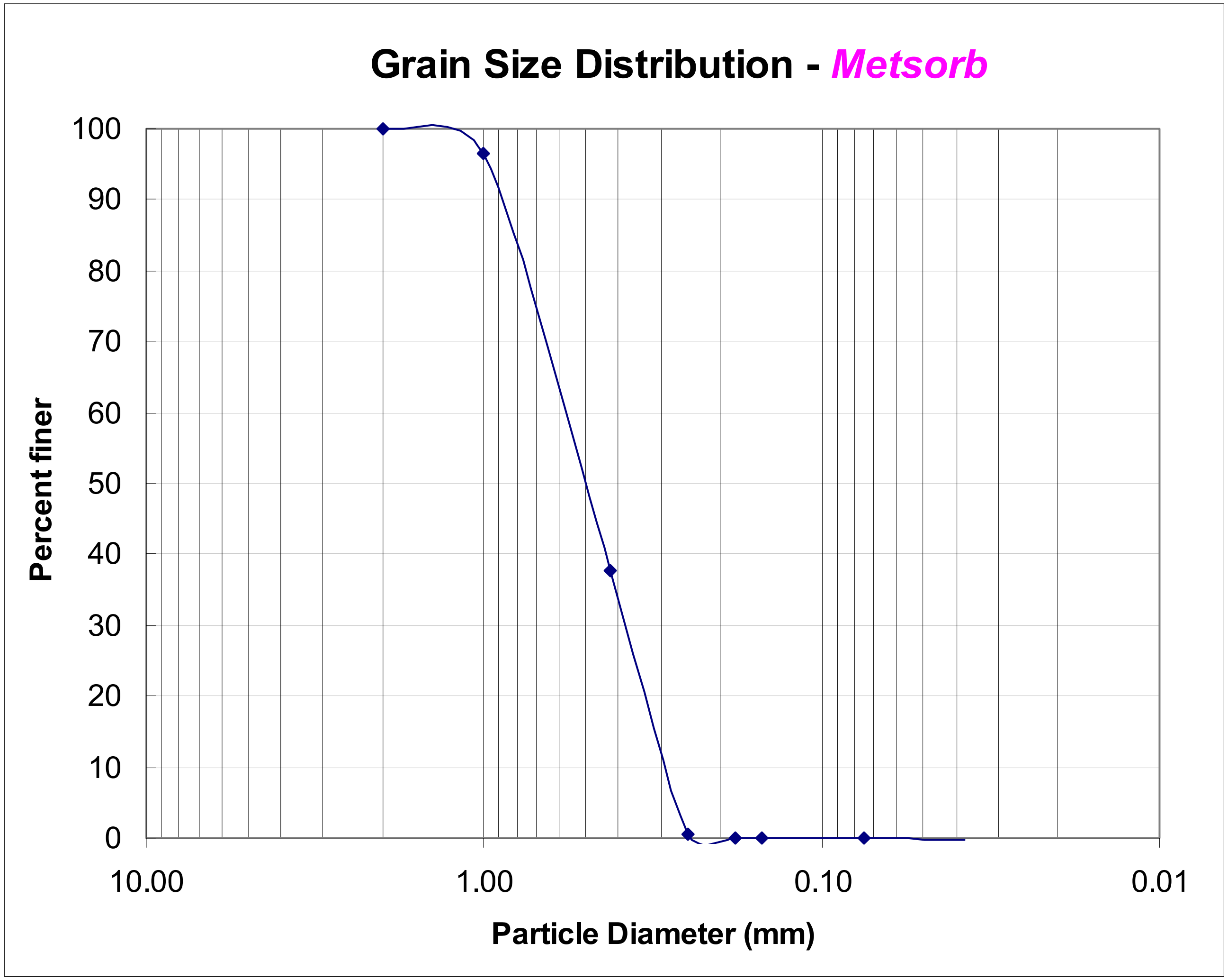
Attachment A
Attrition Loss Data by Media Type

Media:	Purolite ArsenXnp					
Total sample mass (g) =		200.00				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.84	477.91	0.07	0.035	99.965
18	1.000	456.39	481.23	24.84	12.420	87.545
40	0.425	439.69	600.2	160.51	80.255	7.290
60	0.250	335.56	348.02	12.46	6.230	1.060
80	0.180	511.48	512.23	0.75	0.375	0.685
100	0.150	323.39	323.72	0.33	0.165	0.520
200	0.075	362.27	362.68	0.41	0.205	0.315
325	0.045	311.49	311.52	0.03	0.015	0.300
400	0.038	377.64	377.67	0.03	0.015	0.285
pan	n/a	341.59	341.69	0.1	0.050	0.235
			Measured mass retained	199.53		
			Total sample mass	200.00		
			% error	0.23		



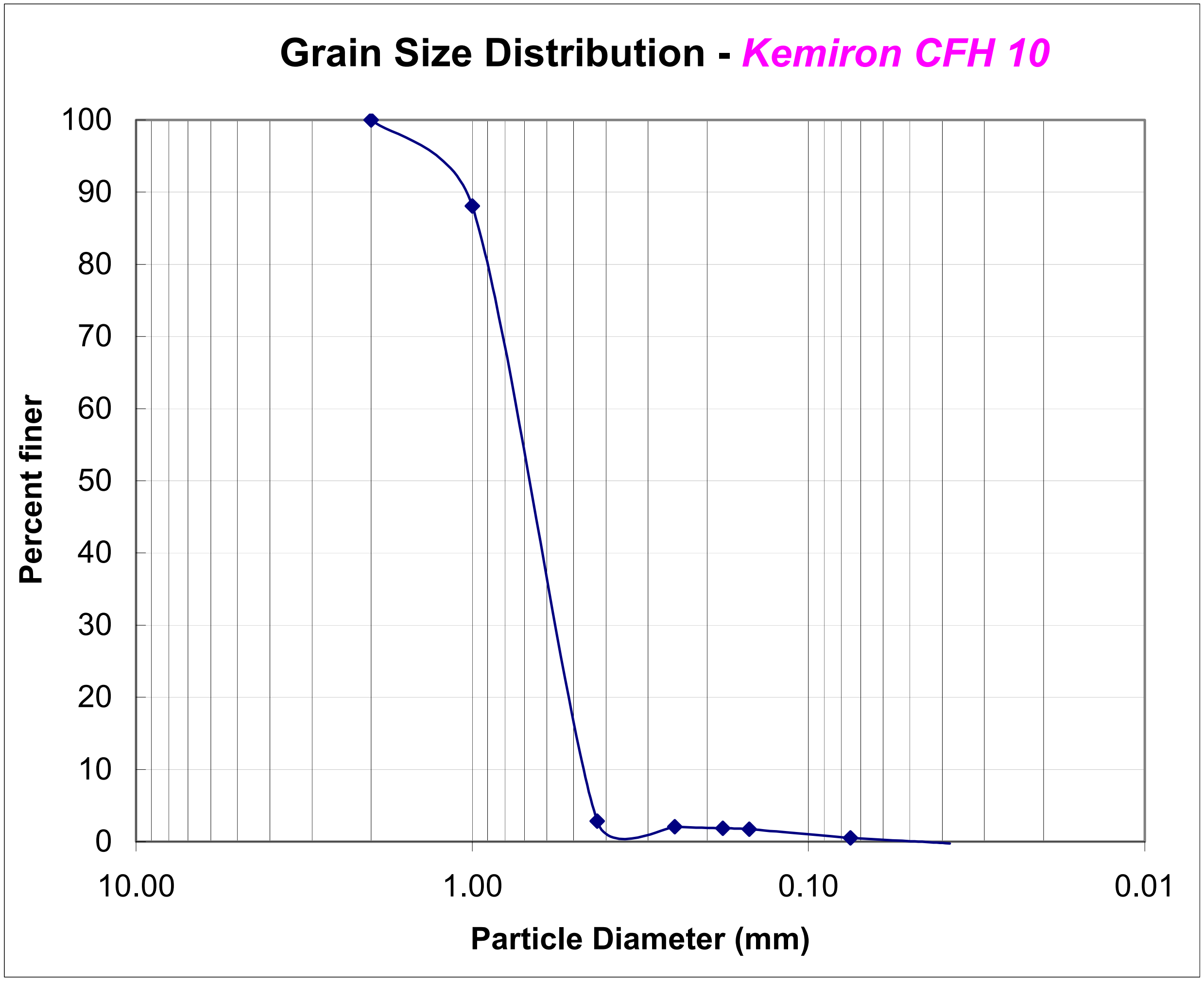
Grain Size Distribution - *ArsenXnp*
Percent finer
100
90
80
70
60
50
40
30
20
10
0
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	Hydroglobe Metsorb					
Total sample mass (g) =		200.00				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.83	477.90	0.07	0.035	99.965
18	1.000	456.19	463.24	7.05	3.525	96.440
40	0.425	440.08	557.79	117.71	58.855	37.585
60	0.250	336.14	410.35	74.21	37.105	0.480
80	0.180	511.78	512.48	0.7	0.350	0.130
100	0.150	323.35	323.50	0.15	0.075	0.055
200	0.075	362.31	362.64	0.33	0.165	-0.110
325	0.045	311.51	311.64	0.13	0.065	-0.175
400	0.038	377.93	378.08	0.15	0.075	-0.250
pan	n/a	341.62	341.85	0.23	0.115	-0.365
			Measured mass retained	200.73		
			Total sample mass	200.00		
			% error	-0.37		

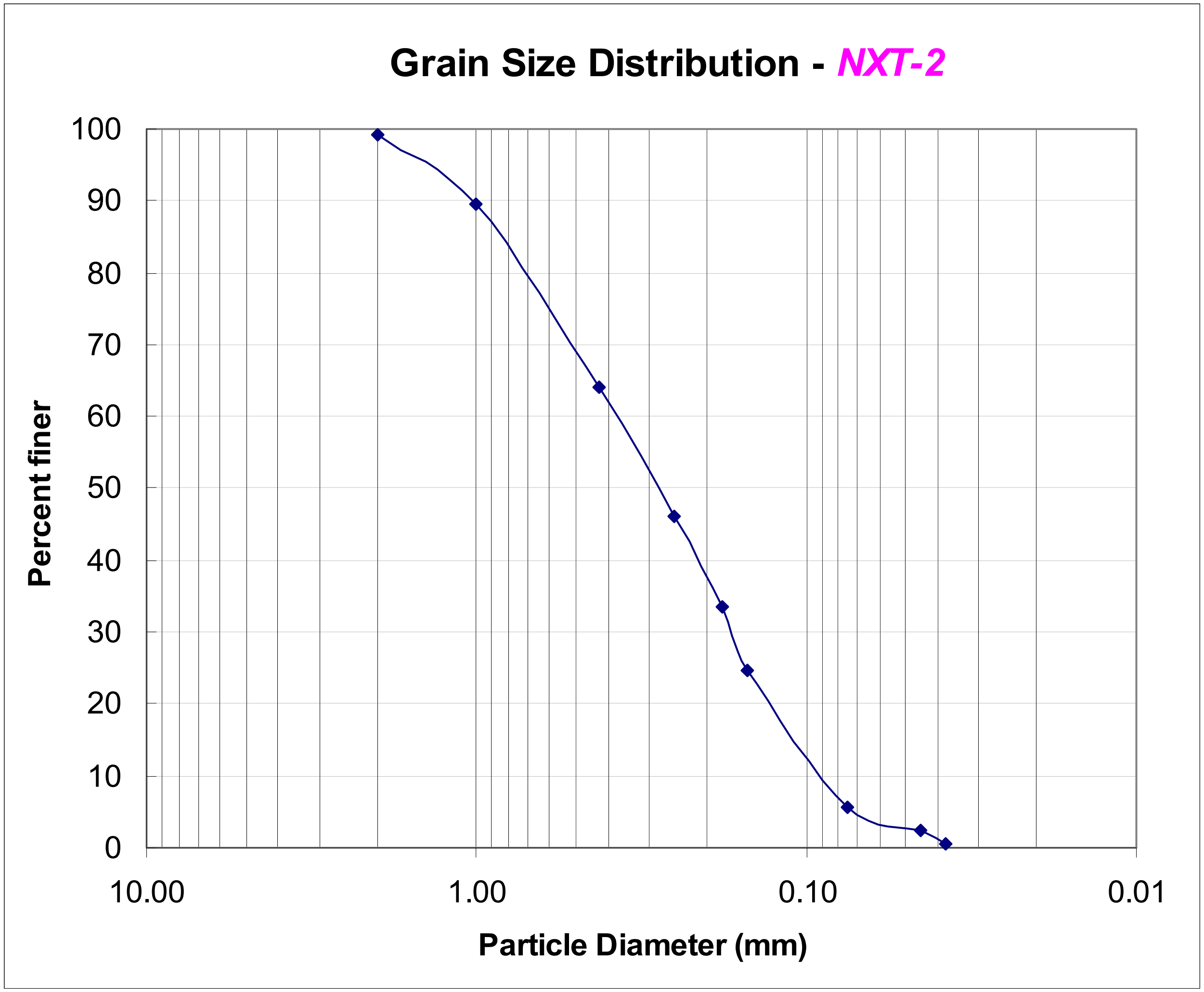

Grain Size Distribution - *Metsorb*
Percent finer
100
90
80
70
60
50
40
30
20
10
0
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	Kemiron CFH 10					
Total sample mass (g) =		200.00				

Sieve No.	Diamater (mm)	Sieve mass (g)	Mass of dry media + sieve (g)	Mass retained (g)	% Retained	% Passing
10	2.000	477.92	477.9	0	0.000	100.000
18	1.000	456.25	480.05	23.8	11.900	88.100
40	0.425	439.79	610.3	170.51	85.255	2.845
60	0.250	335.61	337.15	1.54	0.770	2.075
80	0.180	511.50	511.98	0.48	0.240	1.835
100	0.150	323.39	323.61	0.22	0.110	1.725
200	0.075	362.33	364.78	2.45	1.225	0.500
325	0.045	311.53	312.65	1.12	0.560	-0.060
400	0.038	377.55	377.91	0.36	0.180	-0.240
pan	n/a	341.64	341.73	0.09	0.045	-0.285
			Measured mass retained	200.57		
			Total sample mass	200.00		
			% error	-0.28		

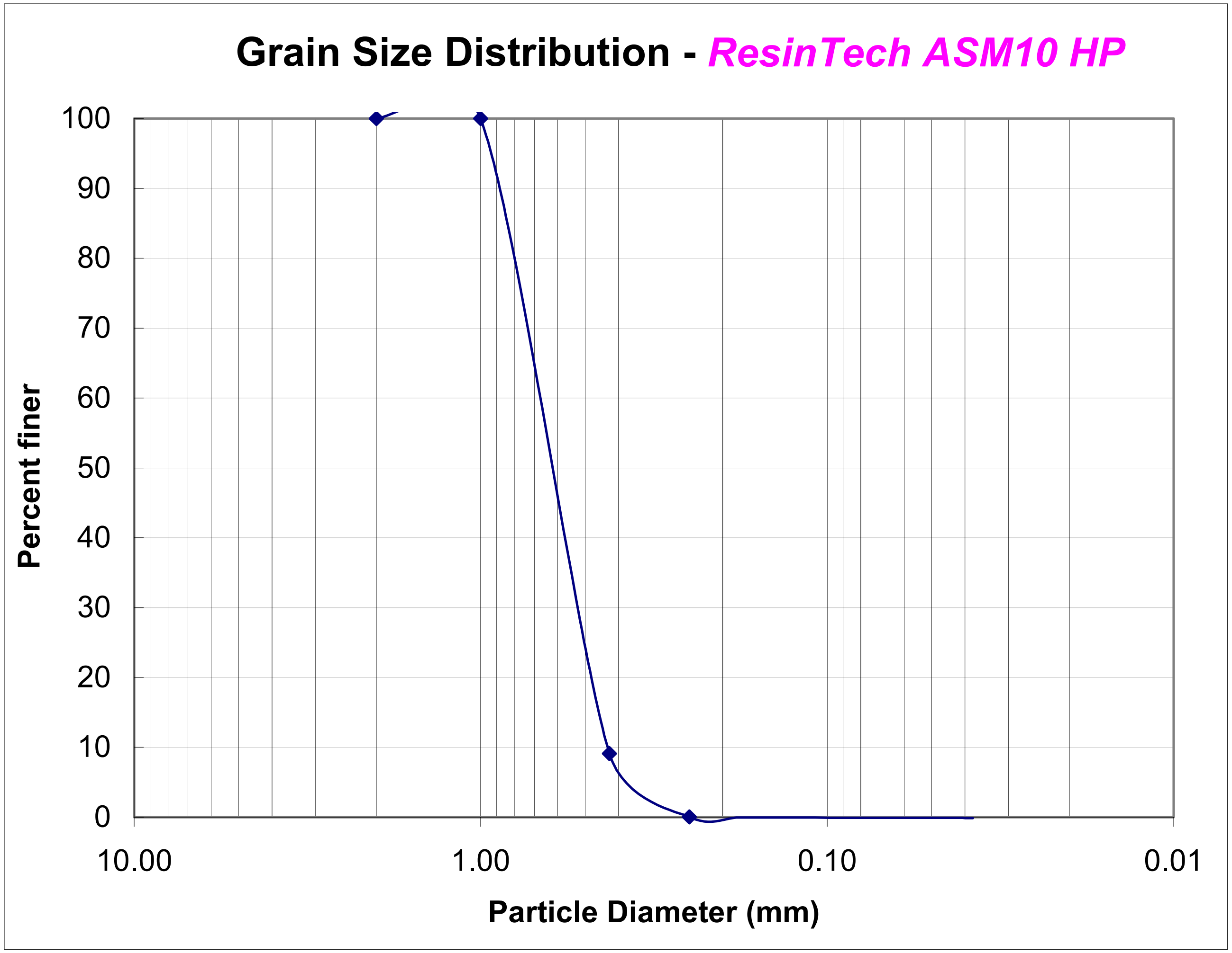

Grain Size Distribution - *Kemiron CFH 10*
100
90
80
70
60
50
40
30
20
10
0
Percent finer
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	Eagle Picher NXT-2					
Total sample mass (g) =		199.99				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.89	479.24	1.35	0.675	99.325
18	1.000	456.21	475.85	19.64	9.820	89.504
40	0.425	439.72	490.48	50.76	25.381	64.123
60	0.250	335.56	371.70	36.14	18.071	46.052
80	0.180	511.50	536.40	24.9	12.451	33.602
100	0.150	323.41	341.16	17.75	8.875	24.726
200	0.075	362.27	400.60	38.33	19.166	5.560
325	0.045	311.47	317.57	6.1	3.050	2.510
400	0.038	377.66	381.58	3.92	1.960	0.550
pan	n/a	341.67	342.28	0.61	0.305	0.245
			Measured mass retained	199.5		
			Total sample mass	199.99		
			% error	0.25		

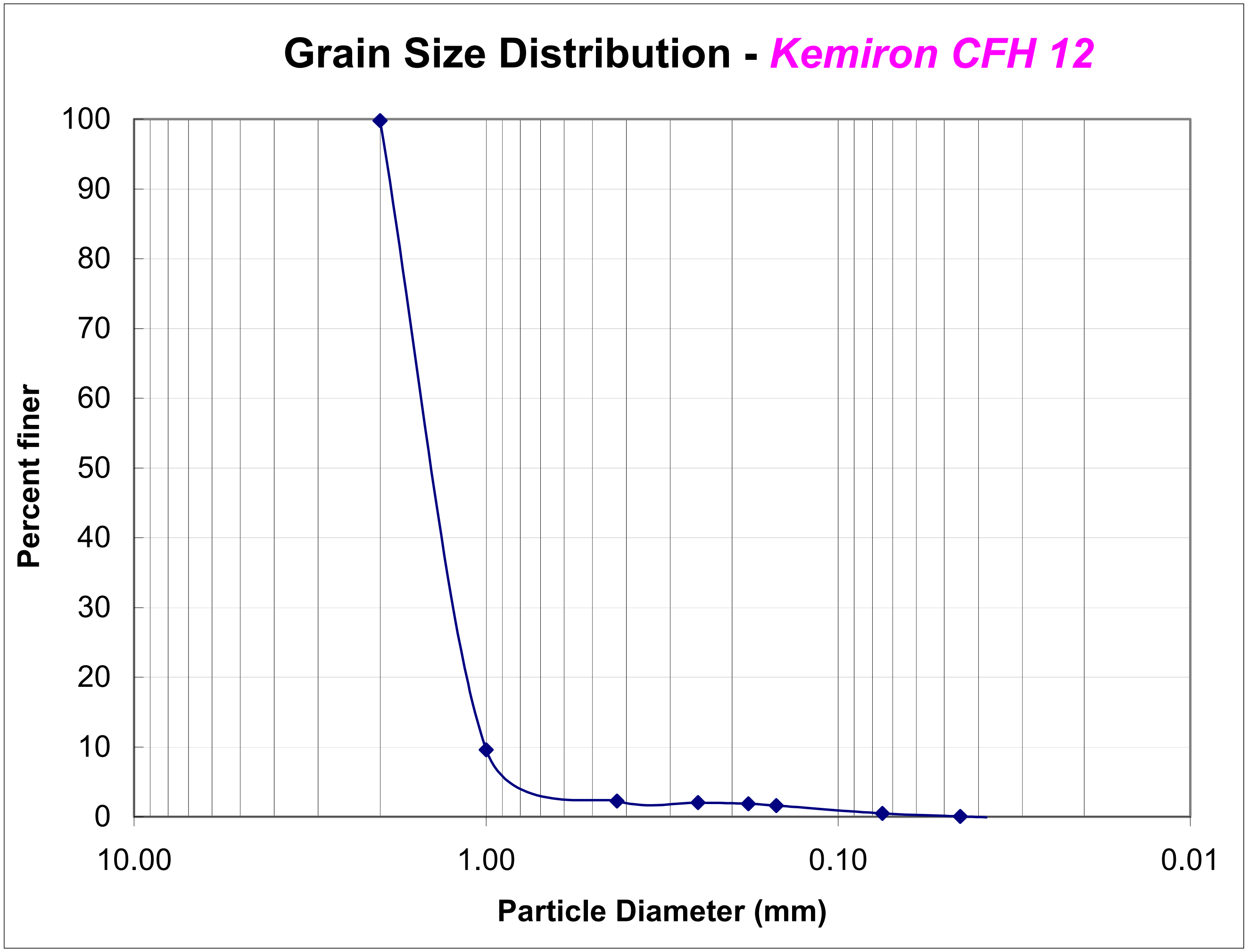


Grain Size Distribution - NXT-2
Percent finer
100
90
80
70
60
50
40
30
20
10
0
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	ResinTech ASM10 HP					
Total sample mass (g) =		200.00				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.87	477.88	0.01	0.005	99.995
18	1.000	456.24	456.24	0	0.000	99.995
40	0.425	439.74	621.5	181.76	90.880	9.115
60	0.250	335.57	353.73	18.16	9.080	0.035
80	0.180	511.59	511.75	0.16	0.080	-0.045
100	0.150	323.42	323.42	0	0.000	-0.045
200	0.075	362.26	362.36	0.1	0.050	-0.095
325	0.045	311.53	311.51	-0.02	-0.010	-0.085
400	0.038	377.65	377.74	0.09	0.045	-0.130
pan	n/a	341.65	341.70	0.05	0.025	-0.155
			Measured mass retained	200.31		
			Total sample mass	200.00		
			% error	-0.16		

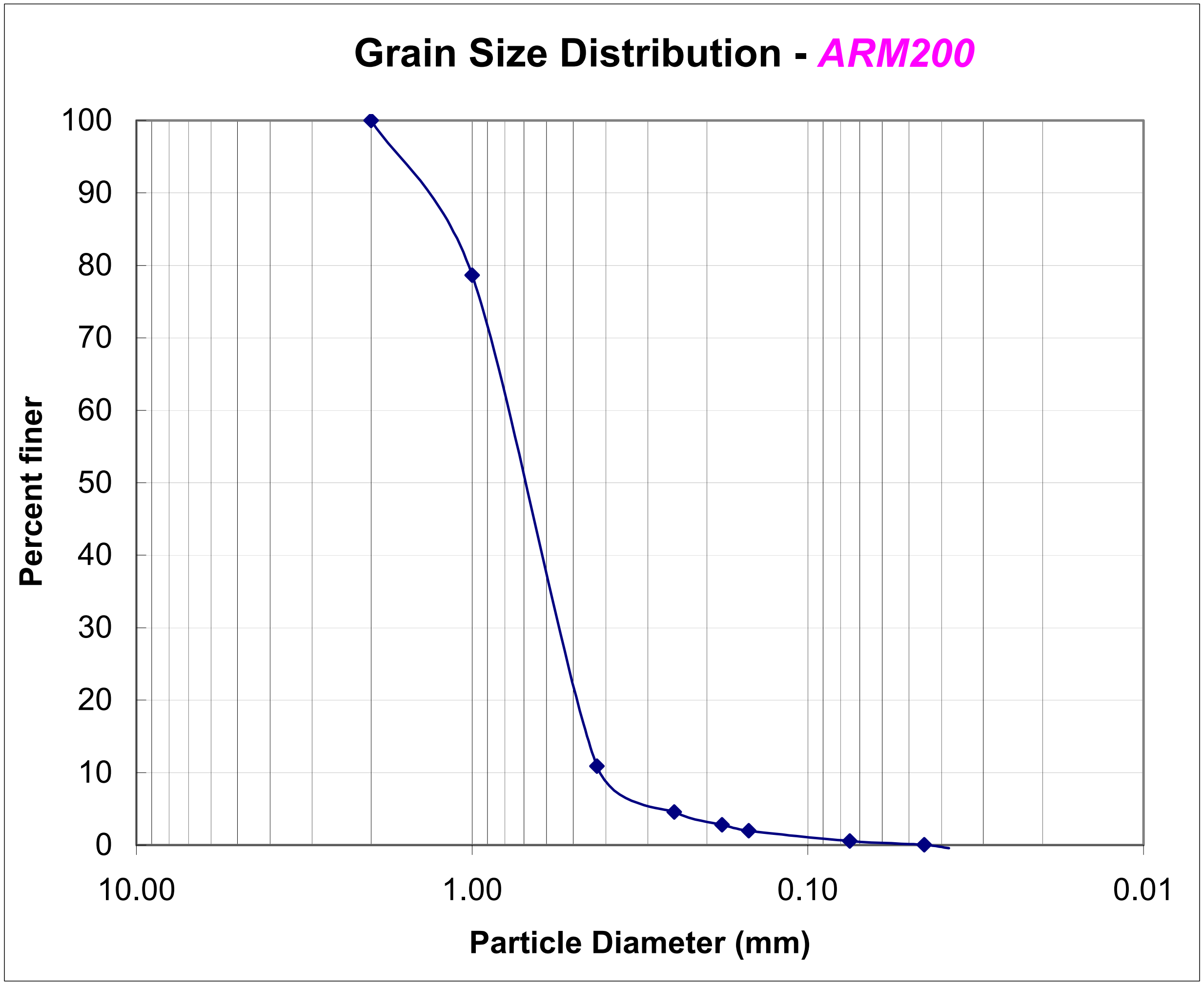

Grain Size Distribution - ResinTech ASM10 HP
100
90
80
70
60
50
40
30
20
10
0
Percent finer
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	Kemiron CFH 12					
Total sample mass (g) =		200.03				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	478.35	478.8	0.4	0.200	99.800
18	1.000	456.22	636.70	180.48	90.226	9.574
40	0.425	439.75	454.40	14.65	7.324	2.250
60	0.250	335.66	336.08	0.42	0.210	2.040
80	0.180	511.50	511.89	0.39	0.195	1.845
100	0.150	323.44	323.94	0.5	0.250	1.595
200	0.075	362.29	364.52	2.23	1.115	0.480
325	0.045	311.53	312.38	0.85	0.425	0.055
400	0.038	377.70	378.01	0.31	0.155	-0.100
pan	n/a	341.60	341.65	0.05	0.025	-0.125
			Measured mass retained	200.28		
			Total sample mass	200.03		
			% error	-0.12		



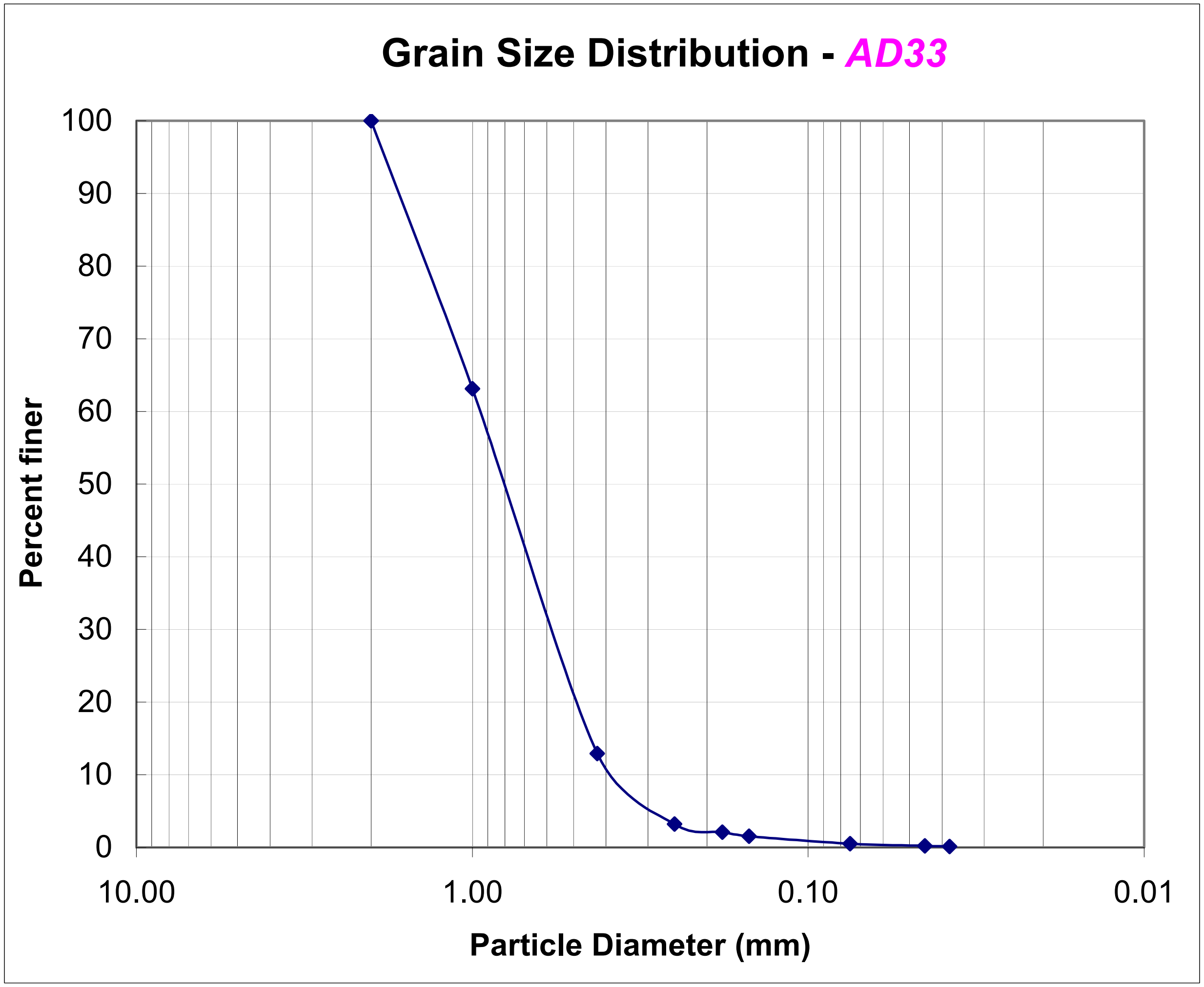
Grain Size Distribution - *Kemiron CFH 12*
100
90
80
70
60
50
40
30
20
10
0
Percent finer
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	Englehard ARM200					
Total sample mass (g) =		199.99				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.94	477.96	0.02	0.010	99.990
18	1.000	456.31	498.96	42.65	21.326	78.664
40	0.425	439.82	575.38	135.56	67.783	10.881
60	0.250	335.62	348.27	12.65	6.325	4.555
80	0.180	511.61	515.09	3.48	1.740	2.815
100	0.150	323.40	325.03	1.63	0.815	2.000
200	0.075	362.32	365.16	2.84	1.420	0.580
325	0.045	311.52	312.58	1.06	0.530	0.050
400	0.038	377.68	378.63	0.95	0.475	-0.425
pan	n/a	341.73	341.87	0.14	0.070	-0.495
			Measured mass retained	200.98		
			Total sample mass	199.99		
			% error	-0.50		



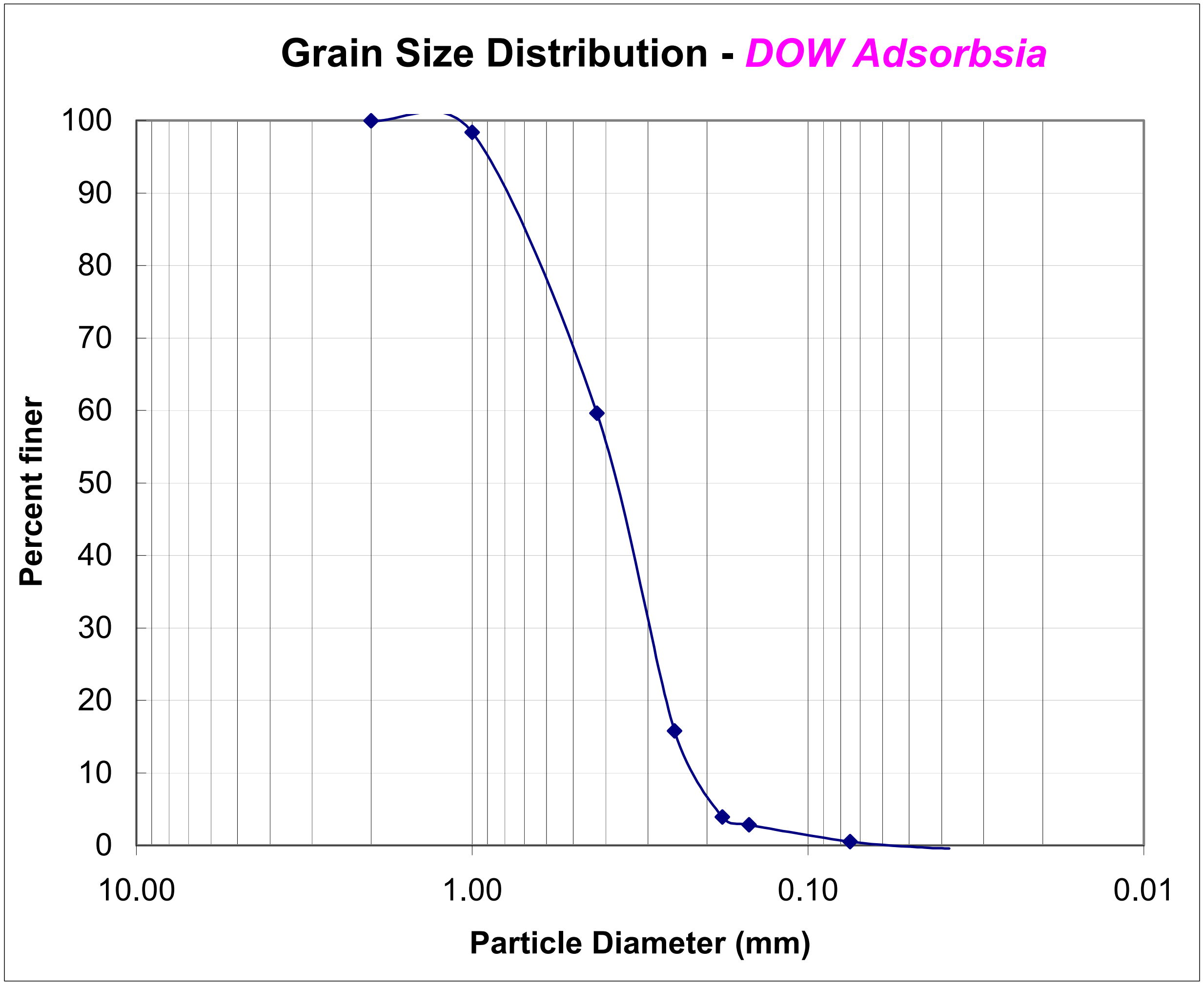
Grain Size Distribution - ARM200
Percent finer
100
90
80
70
60
50
40
30
20
10
0
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	Adedge AD33					
Total sample mass (g) =		200.02				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.98	478.01	0.03	0.015	99.985
18	1.000	456.26	529.97	73.71	36.851	63.134
40	0.425	439.88	540.30	100.42	50.205	12.929
60	0.250	335.93	355.37	19.44	9.719	3.210
80	0.180	511.61	513.86	2.25	1.125	2.085
100	0.150	323.35	324.39	1.04	0.520	1.565
200	0.075	362.46	364.59	2.13	1.065	0.500
325	0.045	312.50	313.07	0.57	0.285	0.215
400	0.038	378.02	378.20	0.18	0.090	0.125
pan	n/a	342.12	342.56	0.44	0.220	-0.095
			Measured mass retained	200.21		
			Total sample mass	200.02		
			% error	-0.09		

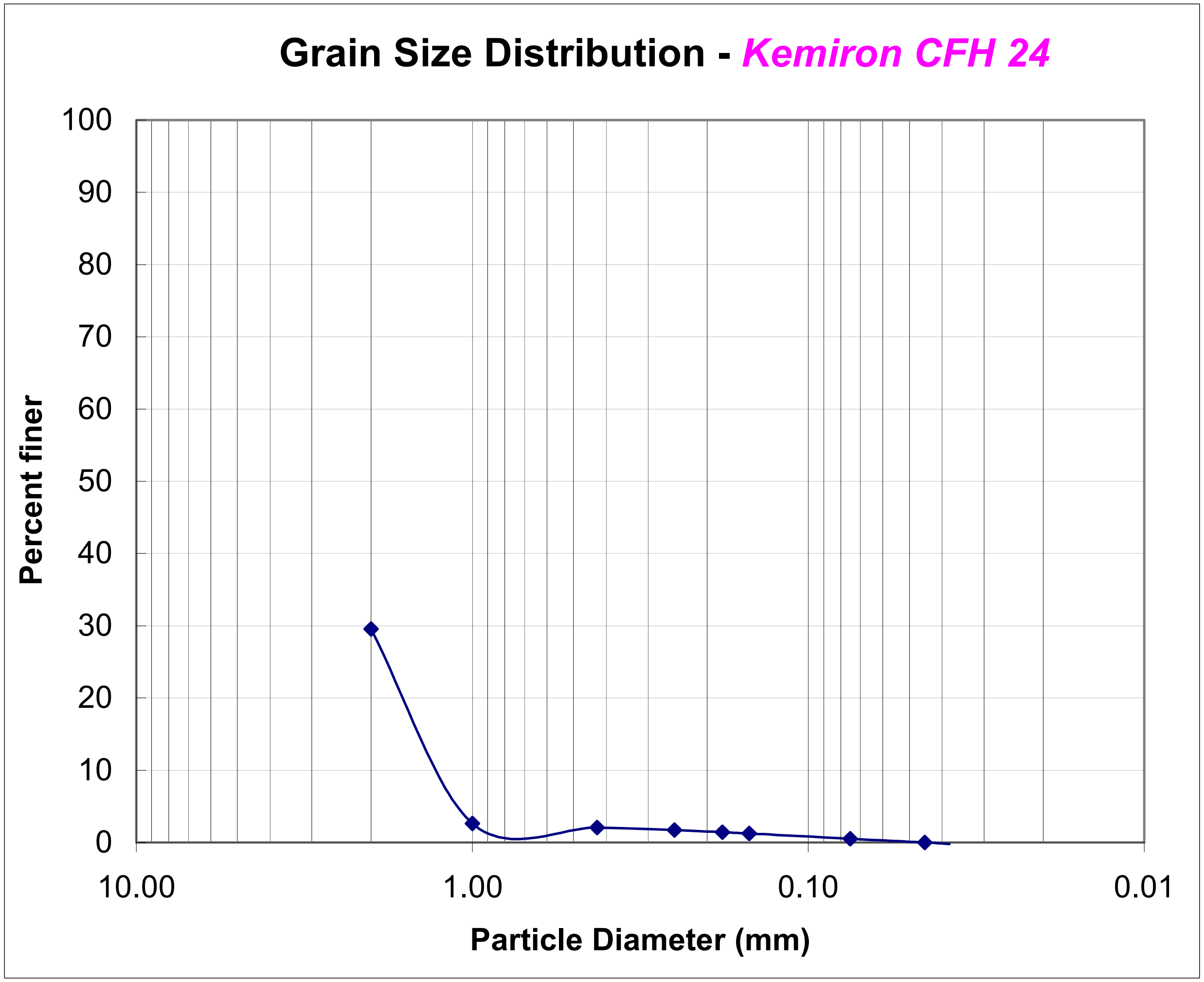


Grain Size Distribution - AD33
100
90
80
70
60
50
40
30
20
10
0
Percent finer
10.00
1.00
0.10
0.01
Particle Diameter (mm)

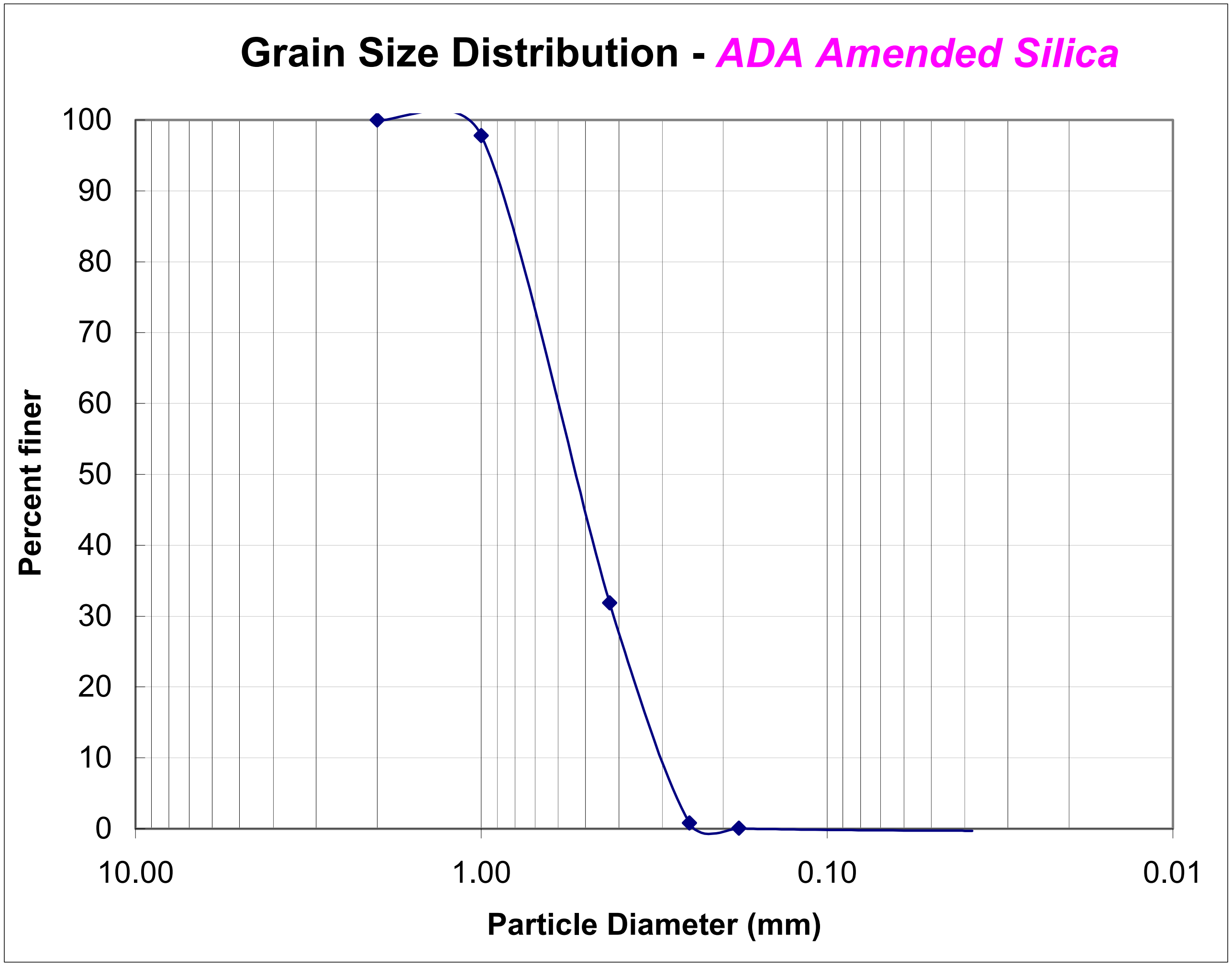
Media:	DOW Adsorbsia					
Total sample mass (g) =		200.01				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.84	477.89	0.05	0.025	99.975
18	1.000	456.22	459.43	3.21	1.605	98.370
40	0.425	439.78	517.28	77.5	38.748	59.622
60	0.250	335.55	423.22	87.67	43.833	15.789
80	0.180	511.55	535.28	23.73	11.864	3.925
100	0.150	323.34	325.52	2.18	1.090	2.835
200	0.075	362.34	366.97	4.63	2.315	0.520
325	0.045	312.12	313.80	1.68	0.840	-0.320
400	0.038	377.69	377.93	0.24	0.120	-0.440
pan	n/a	341.63	341.73	0.1	0.050	-0.490
			Measured mass retained	200.99		
			Total sample mass	200.01		
			% error	-0.49		


Grain Size Distribution - DOW Adsorbsia
Percent finer
100
90
80
70
60
50
40
30
20
10
0
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	Kemiron CFH 24					
Total sample mass (g) =		199.99				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.87	618.7	140.83	70.419	29.581
18	1.000	456.21	510.09	53.88	26.941	2.640
40	0.425	439.75	440.86	1.11	0.555	2.085
60	0.250	335.57	336.28	0.71	0.355	1.730
80	0.180	511.57	512.15	0.58	0.290	1.440
100	0.150	323.35	323.77	0.42	0.210	1.230
200	0.075	362.32	363.79	1.47	0.735	0.495
325	0.045	311.52	312.50	0.98	0.490	0.005
400	0.038	377.69	378.12	0.43	0.215	-0.210
pan	n/a	342.58	342.08	-0.5	-0.250	0.040
			Measured mass retained	199.91		
			Total sample mass	199.99		
			% error	0.04		

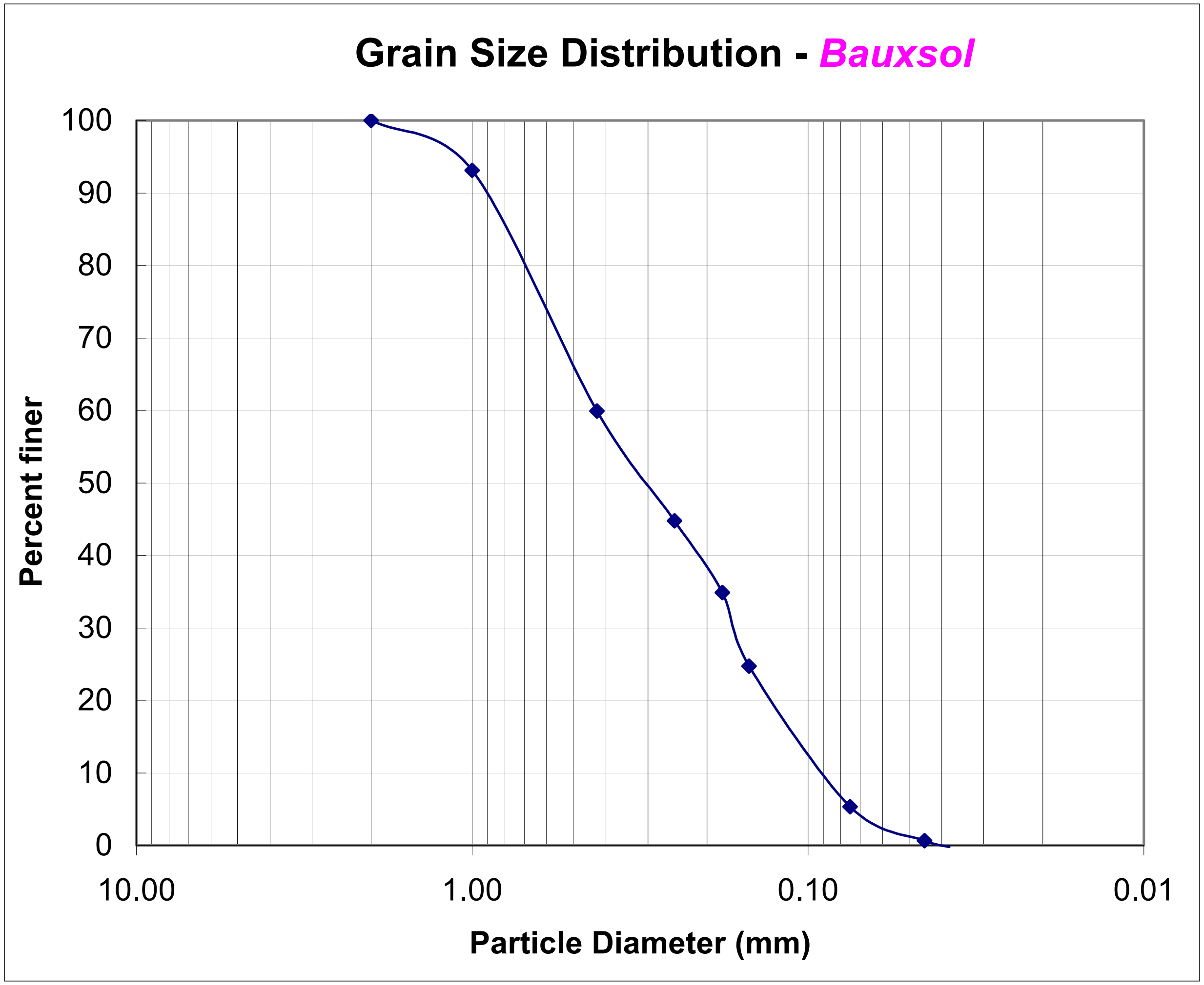

Grain Size Distribution - Kemiron CFH 24
100
90
80
70
60
50
40
30
20
10
0
Percent finer
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	ADA Amended Silica					
Total sample mass (g) =		200.00				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.88	477.89	0.01	0.005	99.995
18	1.000	456.21	460.59	4.38	2.190	97.805
40	0.425	439.76	571.62	131.86	65.930	31.875
60	0.250	335.59	397.68	62.09	31.045	0.830
80	0.180	511.49	512.94	1.45	0.725	0.105
100	0.150	323.35	323.64	0.29	0.145	-0.040
200	0.075	362.30	362.65	0.35	0.175	-0.215
325	0.045	311.50	311.59	0.09	0.045	-0.260
400	0.038	377.66	377.78	0.12	0.060	-0.320
pan	n/a	341.65	341.65	0	0.000	-0.320
			Measured mass retained	200.64		
			Total sample mass	200.00		
			% error	-0.32		

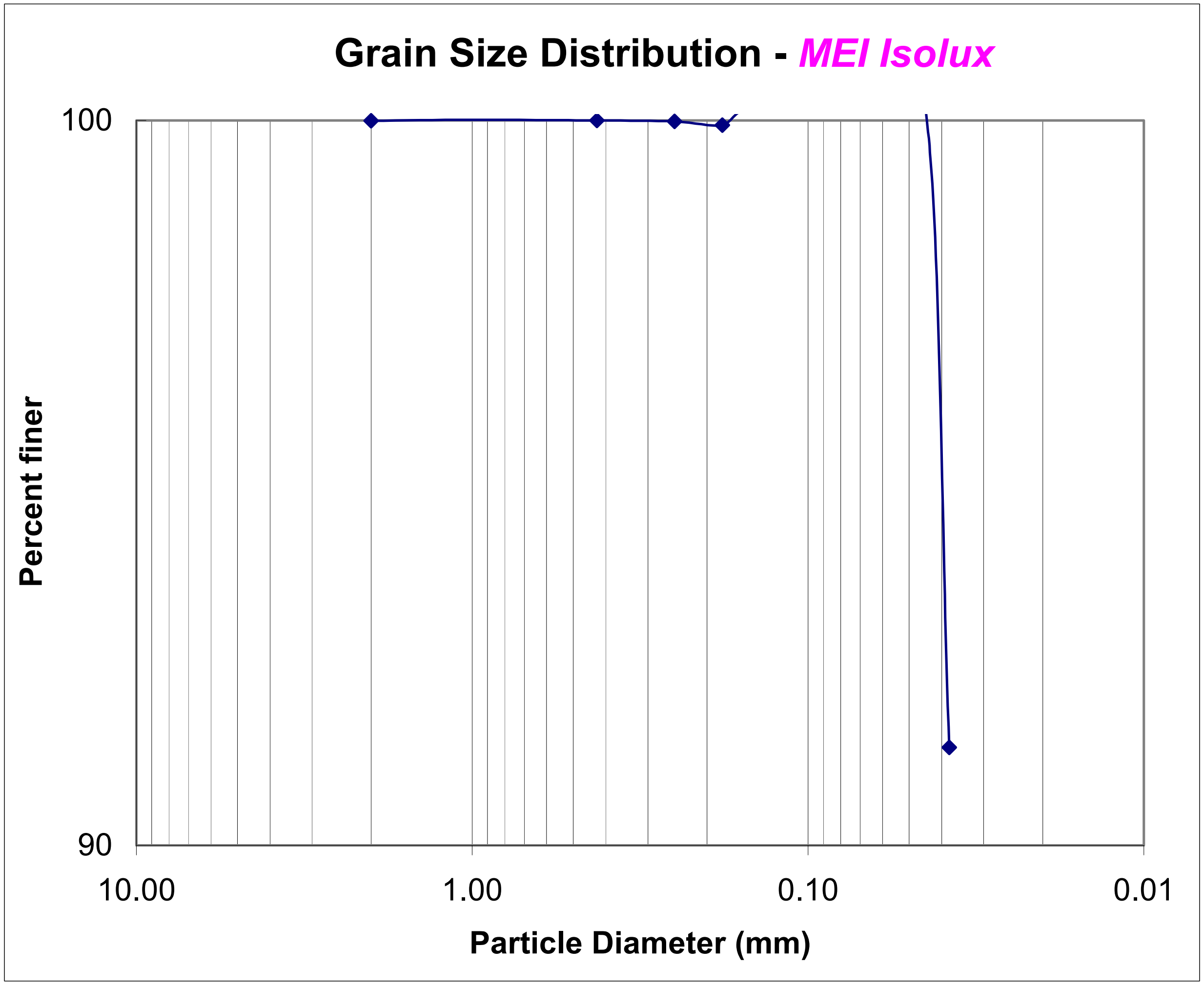


Grain Size Distribution - ADA Amended Silica
100
90
80
70
60
50
40
30
20
10
0
Percent finer
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	Virotec Bauxsol					
Total sample mass (g) =		199.98				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.94	477.95	0.01	0.005	99.995
18	1.000	456.24	469.98	13.74	6.871	93.124
40	0.425	440.14	506.54	66.4	33.203	59.921
60	0.250	335.83	366.08	30.25	15.127	44.794
80	0.180	511.57	531.36	19.79	9.896	34.898
100	0.150	323.40	343.75	20.35	10.176	24.722
200	0.075	362.30	401.04	38.74	19.372	5.351
325	0.045	311.46	320.86	9.4	4.700	0.650
400	0.038	377.61	379.37	1.76	0.880	-0.230
pan	n/a	341.88	341.80	-0.08	-0.040	-0.190
			Measured mass retained	200.36		
			Total sample mass	199.98		
			% error	-0.19		


Grain Size Distribution - *Bauxsol*
Percent finer
100
90
80
70
60
50
40
30
20
10
0
10.00
1.00
0.10
0.01
Particle Diameter (mm)

Media:	MEI Isolux					
Total sample mass (g) =		199.99				
Sieve No.	**Diamater (mm)**	**Sieve mass (g)**	**Mass of dry media + sieve (g)**	**Mass retained (g)**	**% Retained**	**% Passing**
10	2.000	477.91	477.92	0.01	0.005	99.995
18	1.000	456.36	456.33	-0.03	-0.015	100.010
40	0.425	439.89	439.91	0.02	0.010	100.000
60	0.250	335.62	335.65	0.03	0.015	99.985
80	0.180	511.55	511.65	0.1	0.050	99.935
100	0.150	324.26	323.80	-0.46	-0.230	100.165
200	0.075	362.39	362.42	0.03	0.015	100.150
325	0.045	312.45	312.28	-0.17	-0.085	100.235
400	0.038	377.68	395.45	17.77	8.885	91.350
pan	n/a	341.93	522.13	180.2	90.105	1.245
			Measured mass retained	197.5		
			Total sample mass	199.99		
			% error	1.25		



Grain Size Distribution - MEI Isolux
100
90
Percent finer
10.00
1.00
0.10
0.01
Particle Diameter (mm)